Information Collection, Monitoring, and Research

Society and ecosystems are complex, unpredictable, and interconnected. The ability of a society to make decisions depends both on the quality of its information and its institutional ability to use that information. For a variety of reasons, resource managers and decision makers, including those involved with forests and rangelands, have had to increasingly cope with these facts during the last decade.

At the ecosystem level, several approaches are being attempted including: 1) habitat protection for diverse species; 2) restoration and enhancement of riparian areas and aquatic resources; and 3) spatially linked reserves comprised of late successional habitat. There are also efforts to understand linkages between different parts of the ecosystem, to discover the varying times and scales of natural processes, and to formulate methods that incorporate information about these linkages into decision-making processes.

This situation is not at all unique to forestry. Uncertainty can be found in many other disciplines such as water supply management, infectious disease control, and earthquake prediction. In other fields, planning and risk management have emerged as the techniques used to assess an uncertain future based on a common understanding of the ways systems function. This understanding is not perfect, but it can be refined through monitoring and focused research. Decision-making involves assessing relative risks and agreeing on what is acceptable and what is not. Decisions are seldom free of risk or consequence.

Environmental prediction is not precise, and typically this is true in matters related to forest and rangeland ecology. The best that can be done is to develop strong conceptual models of the processes involved, consistent ways of evaluating them, and a general agreement on the authority responsible for the quantitative evaluation of probable outcomes. Increasingly, it also means integrating scientific analyses with stakeholder involvement and community decision-making. In many cases, stakeholders are the only ones that can define acceptable risk and implement programs fashioned by this understanding.

In order to summarize information concerning efforts to conduct research, information collection and monitoring, several topics are reviewed:

- Information collection and monitoring efforts on forest and rangeland sustainability;
- Research structure and efforts for forest and rangelands including governmental agencies and academic, private, and non-government foundations; and
- Research funding levels and the focus of research topics.

Findings on information collection on California forest and rangelands

In the context of tracking forest and rangeland sustainability, information must be collected that portrays the status of a resource and defines how it will change over time. In order to accomplish these goals, there have been extensive efforts during the last decade to assemble existing data in order to generate a model of forest and rangeland ecosystems. The federal government has especially been involved in these efforts at the pure science level as well as through focused efforts to bring scientists into the design of new approaches to land management. Two of the most significant examples relevant to California are the Northwest Forest Plan (NWFP) and the Sierra Nevada Ecosystem Project (SNEP). Similar efforts have also taken place on private lands as landowners develop Habitat Conservation Plans (HCPs) to address threatened and endangered species and water quality issues under the federal Clean Water Act. See the Assessment document Institutional Framework: Governance Shifts in the 1990s for more information on broad scale plans. More recently, collaboration among two State agencies (Resources and Cal EPA) and five of their constituent units (CDF, DFG, CGS, DWR, NCRWQCB) for assessment of North Coast watersheds demonstrates how State agencies are collaborating to develop and disseminate information and assessment results.

There have been extensive efforts during the last decade to assemble existing data in order to generate a model of forest and range ecosystems.

Data is available in at least 20 general categories concerning elements of forest and rangeland sustainability. These categories involve various types of information, collected by different agencies, characterized by different update frequencies and accuracies. While difficult to generalize, Table 1 presents a summary by class of information type.

Table 1. Forest and rangeland information collection

Class of information type	Agencies	Typical frequency of updates	Typical accuracy of information
Ecological systems			
Biodiversity	Numerous	Varied	Varied
Conifer forest			
General inventory	U.S. Forest Service (USFS), landowners	10 years	High
Condition	USFS, U.S. Bureau of Land Management (BLM), California Department of Forestry and Fire Protection (CDF), landowners		
Specialized stand characteristics or focus	USFS, BLM, landowners, CDF	5 years	High
Hardwood forest			
General inventory	USFS		High
Condition	USFS, University of California (UC), ranchers	Varied	Varied
Specialized stand characteristics or focus	USFS, UC, CDF	Varied	Varied
Range			
General inventory	USFS, BLM, U.S. Natural Resources Conservation Service (NRCS), CDF	5-10 years	High when updated
Condition	USFS, BLM, NRCS	5-10 years	Varied
Specialized stand characteristics or focus	USFS, CDF	5 years	High
Wildlife			
Populations	U.S. Fish and Wildlife Service (FWS), California Department of Fish and Game (DFG), UC, landowners	Varies by species	Varies by species
Habitat condition	FWS, DFG, UC, landowners	Varies by species	Varies by species
Fish			
Populations	FWS, DFG, National Marine Fisheries Service (NMFS), landowners	Varies by species	Varies by species
Habitat Condition	FWS, DFG, NMFS, landowners	Varies by species	Varies by species
Soils, geology			
Location	U.S. Geological Survey (USGS), NRCS	Periodic	Varied
Sensitivity to erosion or movement	USGS, NRCS	Periodic	Varied
Wildfire threat			
History and behavior of wildfire	USFS, BLM, U.S. National Park Service (NPS), CDF	Annual	High
Communities and assets at risk	USFS, BLM, CDF, local fire agencies	Periodic	High
Impact of fire protection forces on losses	USFS, BLM, CDF	Annual	High
Water quality			
Location of beneficial uses/water quality standards	U.S. Environmental Protection Agency (EPA), Regional Water Quality Control Boards (RWQCBs), DFG, U.S. Army Corps of Engineers (USACE)	Periodic	Varied
Condition of meeting beneficial uses	EPA, RWQCBs, DFG, USACE, industry, landowners	Periodic	Varied, but high when updated
Special measures	EPA, RWQCBs, DFG, USACE, industry, landowners	Periodic	Varied
Water quantity	DWR, U.S. Bureau of Reclamation	Annual	High
Air quality			
Location of air quality standards	EPA, California Air Resources Board (ARB), Air Quality Management Districts (AQMDs)	Periodic	High
Conditions of meeting standards	EPA, ARB, AQMDs, industry, landowners	Annual	High
Special measures	EPA, ARB, AQMDs	Periodic	Varied
Recreation			
Facility use	NPS, California Department of Parks and Recreation (DPR), USFS, BLM, CDF	Annual	High
Facility condition	NPS, DPR, USFS, BLM, CDF	Annual	High
Focused information	DPR contracts	Periodic	High
Demographic			
Population numbers and location	U.S. Census Bureau, California Department of Finance (DOF), California Department of Education (CDE), non-profits	Annual to periodic	High
Population characteristics	U.S. Census Bureau, DOF, CDE, non-profits	Annual to periodic	High
Economic			
Income, unemployment, and related information	Varied	Annual	High
Economic activity by sector	Varied	Annual	High
Land use			
General land use types and changes	UC, California Department of Water Resources (DWR), California Department of Conservation (DOC), CDF, UC, non-profits, local government	Annual to five years	Medium to High
Forest and range uses	Varied, including non-profits	Five years	Varied
Open space	Varied, including non-profits	Annual to periodic	High

Table 1 (continued). Forest and rangeland information collection

Class of information type	Agencies	Typical frequency of updates	Typical accuracy of information
Forest and range pests			
Location, extent of pests, changing conditions	CDF, USFS, BLM, UC, California Department of Food and Agriculture (CDFA), U.S. Department of Agriculture (USDA) (other than USFS), industry, non-profits	Annual but depends on pest	Varied
Introduction of new pests	USDA, CDFA, UC, landowners	Periodic	Varied
Urban forests	USDA, CDF, utilities	Periodic	Varied
Forest extent and condition	California Energy Commission (CEC), CDF, local agencies, non-profits	Periodic	High
Urban wood waste disposal	California Integrated Waste Management Board (CIWMB)	Annual	High
Energy resources	CEC, industry, U.S. Department of Energy (DOE	Annual	Varied
Renewable resource locations and potentials	CEC, industry, U.S. Department of Energy (DOE), non-profits	Periodic	High when updated
Forest and range biomass	CEC, industry, DOE, non-profits	Periodic	High when updated
Climate change	Varied	Ongoing	Varied
Carbon sequestration	CEC, California Climate Action Registry	Ongoing	Varied

Source: Fire and Resource Assessment Program (FRAP), 2002a

Monitoring on California forest and rangeland

In the last decade, there has been an increased emphasis on monitoring and research. "Monitoring" is distinct from research and is often used to describe a method of information collection tied to management or planning goals. The development of monitoring approaches often involves the creation of common standards and protocols to collect and use information. An "analysis" or "assessment" combines research and monitoring with other available information to examine a common problem.

Monitoring activities of governmental agencies, private landowners, and watershed groups that collect information on the status of natural processes or the impact of management actions on these processes have increased during the last decade. One of the most significant examples is the effort of many larger forest landowners to monitor in-stream and riparian conditions, especially on the North Coast. As of 2002, these companies are monitoring 19 different factors important to riparian habitat. The number of factors being monitored by each company varies, but most companies are collecting information on four or more factors. The factors and number of companies collecting information for each factor are listed in Table 2.

Table 2. California forest landowner riparian monitoring

Factor	Number of companies	Factor	Number of companies
Temperature	12	Flow	6
Channel bed/bank	8	Turbidity	5
Cross section	7	Roads	8
Canopy	7	Air	5
Riparian	7	Large woody debris	6
Pebble gravel	7	Mass wasting	3
Fine sediments	7	Permeability	3
Invertebrates	8	Nutrients	2
Fish/vertebrates	8	Chemicals	2
Fish habitat	8		

Source: Forest Science Project, 2002

In addition to use of monitoring practices to collect information about the status of a resource, it can be used to trace the status of a program or practices. In this context, there are three types of information collection and monitoring methods used on California's forest and rangeland:

- Implementation;
- Effectiveness; and
- Validation.

Implementation monitoring collects information that indicates whether the actions or requirements of a program or practice are being accomplished. An example of this method is the implementation monitoring program supervised by the Regional Implementation Monitoring Team under the NWFP (Baker, et al., 2000). This program attempts to verify that NWFP standards and guides are being implemented in key areas such as old growth forests, northern spotted owl and marbled murrelet indicators, watershed health, social and economic values, and tribal relations.

Effectiveness monitoring verifies that actions meet the goals or desired outcome of a program or management practice. An example of this approach is the Hillslope Monitoring Program of the California State Board of Forestry and Fire Protection (BOF). See the online document Hillslope Monitoring Program: Monitoring Results from 1996 through 1998 for more information (BOF, 1999). The purpose of this effort is to document whether or not existing rules effectively protect water quality from operations related to roads, skid trails, landings, watercourse crossings, and watercourse and lake protection zones. To accomplish this mission, the monitoring study group records and analyzes information related to the results of rule implementation, such as erosion from properly constructed skid trails.

Validation monitoring attempts to confirm cause and affect relationships between actions and goals. These efforts are associated with specific research that examines the validity of assumptions or hypothesized relationships that support management actions. Examples of this method during the last decade can be found in documentation of the nesting and habitat behavior of the Northern Spotted Owl. These studies have guided subsequent survey and protection approaches. Validation monitoring is also used in numerous social research efforts.

State and federal agencies in California maintain a wide range of monitoring programs; however, most concentrate on implementation and effectiveness monitoring. See Table 3 for examples of agencies with monitoring programs (listed by subject area).

Table 3. Agencies with monitoring programs

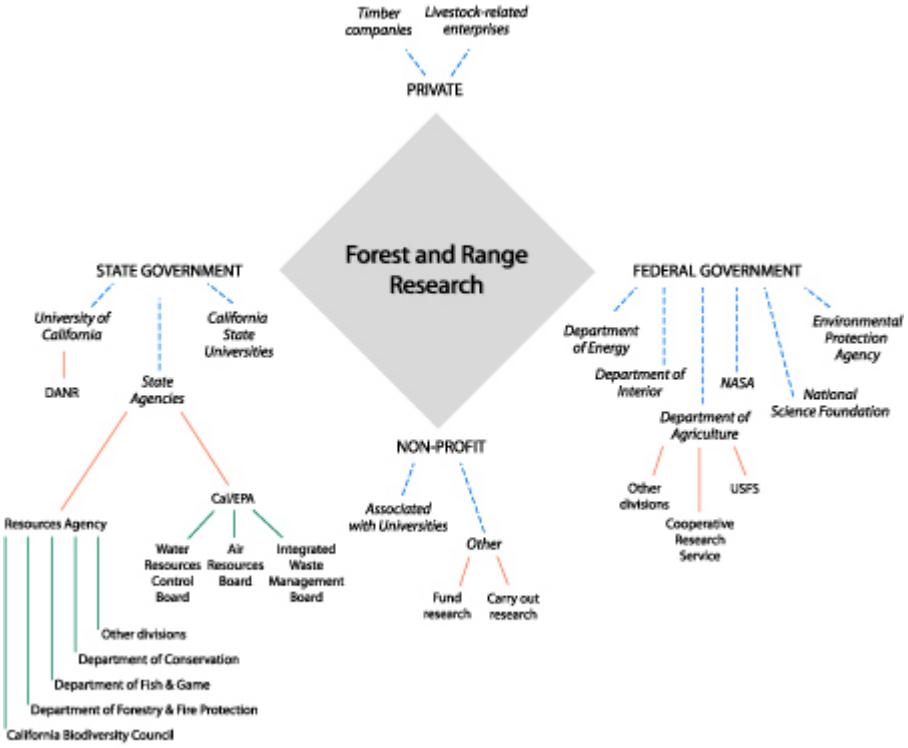
Resource type	Practices compliance	Practices effectiveness	Assumptions validation
Forest management	USFS, CDF, BLM, NPS, landowners, non-profits	USFS, CDF, BLM, NPS, landowners, non-profits	UC, industry
Range management	UC, California State Water Resources Control Board (SWRCB), USFS, BLM, NPS, NRCS, non-profits	UC, SWRCB, landowners, USFS, BLM, NPS, NRCS, non-profits	UC
Maintenance of wildlife populations and habitat diversity	FWS, DFG, USFS, BLM, NPS, industry, non-profits	FWS, DFG, industry, non-profits	UC, FWS, DFG, industry
Maintenance of fish populations and habitat	NMFS, DFG, industry, non-profits	DFG, NMFS, non-profits	UC, DFG, NMFS, industry, non-profits
Maintenance of soils	USGS, California Geological Survey (CGS), non-profits, NRCS	USGS, NRCS	
Protection of water quality	SWRCB, RWQCBs, USACE, industry	SWRCB, RWQCBs USACE, non-profits	EPA
Protection of air quality	ARB, EPA, industry	ARB, EPA	ARB, EPA
Provision of quality recreation and wilderness	NPS, CPR, USFS, BLM	NPS, CPR, USFS, BLM	
Minimizing impact of forest and range pests	CDF, USFS, BLM, UC, CDFA, USDA (other than USFS), non-profits	CDF, USFS, BLM, UC, CDFA, USDA (other than USFS), non-profits	UC
Providing for renewable energy	DOE, CEC, non-profits, industry		
Disposing urban wood waste	CIWMB, non-profits, industry	CIWMB	CIWMB
Promote carbon sequestration	In progress		

Source: FRAP, 2002a

Findings on the research structure of California forest and rangeland

Forest research relevant to California occurs through a number of forums. These include landowners and private industry, educational institutions, and government. Governmental agencies may conduct research directly or fund other entities. Landowners, private industry, and non-profit foundations often contribute funding for research. See Figure 1 for an overview of the structure.

Figure 1. Forest and rangeland research



Source: FRAP, 2002a

Forestry research/information at the federal level

Eight federal agencies maintain a research presence in areas related to forest and rangeland. These are summarized in Table 4.

Table 4. Federal research and information

Federal agency	Research and information
Agricultural Research Service (ARS)	The service conducts research on foods, fibers, soil, water, and other natural resources. ARS mission is to solve technical agricultural problems. Agency does not have a regulatory mission, but conducts research for other regulatory agencies such as Animal and Plant Health Inspection, the Food and Drug Administration, and the EPA. Most of ARS research is conducted in-house.
U.S. Cooperative State Research, Education, and Extension Service (CSREES)	CSREES funds research that addresses problems of national and regional importance to agriculture, forestry, and related sciences. Approximately half of its budget is designated for formula-based funding land grant universities. The remainder of the budget funds competitive grants and congressionally mandated special research.
U.S. Forest Service (USFS)	Under the Forest and Rangeland Renewable Resources Planning Act of 1974, USFS conducts periodic natural resource assessments, provides periodic reviews of its research activities, and presents a research program every 5 years. Under the Forest and Rangeland Renewable Resources Research Act of 1978, the USFS conducts research through its Forestry Research Stations, one of which is in California. Most research is internal, but about 10 percent is external.
National Oceanic and Atmospheric Administration	The bureau describes and predicts changes in the global environment. It is also mandated to conserve and manage the nation's coastal and marine resources. NOAA consists of five major offices: NMFS, the National Ocean Service, the Office of Oceanic and Atmospheric Research, the National Weather Service, and the National Environmental Satellite Data and Information Service. The Office of Oceanic and Atmospheric Research, the National Ocean Service, and NMFS conduct much of the research. The NMFS conducts its research through five regional science centers in about 30 laboratories.
U.S. Department of Energy (DOE)	DOE conducts research and development on a variety of topics, including fossil, fusion, and nuclear energy production, energy conservation, renewable energy, biological and environmental research, materials science, engineering and geosciences, and many other topics. Approximately 80 percent of the budget is used to support research, research facilities, and related activities within the department and its national laboratory system.
U.S. Environmental Protection Agency (EPA)	The agency concentrates on research related to human health and the natural environment. The EPA funds research for a variety of air and water-related topics through its Office of Research and Development. The majority of the research budget is used for internal research, but a significant portion also is used for external research.
U.S. Geological Survey (USGS)	The service is the principal research agency of the U.S. Department of the Interior (DOI). It provides biological, geologic, topographic, and hydrologic information. USGS has four research divisions: Biological Resources, Water Resources, Geologic, and National Mapping Program. The divisions support research conducted by USGS scientists, as well as providing competitive grants for external scientists.
National Aeronautics and Space Administration (NASA)	NASA conducts research in earth science, space science, and related applications. Funding mechanisms are determined by the research goal.
National Science Foundation (NSF)	NSF is an independent federal agency whose goal is to advance scientific and engineering progress in the United States as well as ensuring the nation's supply of scientists, engineers, and science educators. Most of the NSF budget is allocated for basic and applied research. NSF supports external research in science and engineering through grants and cooperative agreements with most universities and other research and education organizations across the country.

Source: U.S. General Accounting Office, 1999

Relative to federal forest and rangeland, the USFS and USGS have historically maintained the largest research presence in California.

The USFS and USGS have historically maintained the largest research presence in California relative to federal forest and rangeland. Research on fish, wildlife, and air and water quality has been influenced by the NMFS, FWS, and EPA. See the online document Research for more information (EPA, 2002). Some of this research has been relevant to forest and rangeland issues in California. Examples include models of air and water-related processes, as well as

tool development that facilitates watershed assessment. The DOE supports research into renewable energy sources, primarily biofuels and biomass.

The USFS maintains the largest forestry-related research branch of any federal agency. The mission of Forest Service Research and Development is to develop and communicate the scientific information and technology needed to protect, manage, use, and sustain forest and range resources (USFS, 2002a). The total research budget in fiscal year (FY) 2002 was approximately $240 million. See the online document Fiscal Year 2002 Budget: Department of Agriculture for more information (U.S. Government Printing Office, 2002a).

Research is conducted at six Forest and Rangeland Experiment Station headquarters and their research work units, the Forest Products Laboratory (FPL), and the International Institute of Tropical Forestry. Research stations typically concentrate on topical or program areas. Two research stations, the Pacific Northwest Research Station (PNW) and Pacific Southwest Research Station (PSW) address a variety of topics related to California forests (PNW, 2002a; PSW, 2002). The FPL in Madison, Wisconsin specializes in wood science and use. See the online document About the Forest Products Laboratory for more information (FPL, 2002a).

PNW conducts forest inventory analysis for California. Funding for the analysis was increased substantially in FY 2002 and the proposed budget for FY 2003. The goal is to completely implement a consistent, annualized inventory in California, Oregon, Washington, Alaska, and the Pacific Islands. Though funding for this program has increased and the net PNW budget is proposed to increase by about $3.6 million, support for other programs relevant to California will diminish. See the online document The FY 2003 President's Proposed Budget for PNW for more information (PNW, 2002b).

PSW conducts a variety of research relevant to California. The main station is located in Albany and field stations exist in Arcata, Redding, Davis, Fresno, and Riverside. Each station concentrates on topical areas of research. Programs of special interest to California include urban impacts on forests, forestry in the Sierra, and issues related to fish, wildlife, and timber management (USFS, 2002b).

The FY 2002 budget exceeded $16.9 million. PSW received an additional $5.5 million of National Fire Plan funding to conduct fire research. In certain cases, PSW receives emergency funds from outside appropriations to deal with critical issues. An example of this scenario occurred in fiscal year 2001. PSW received $3 million in emergency funds from outside the USFS Research and Development appropriations budget to support Sudden Oak Death (SOD) efforts in California (USFS, 2002b).

The FPL in Madison is a leader in wood research (FPL, 2002b). Examples of ongoing wood-related research include use of automated scanning technology used to inspect high-quality lumber for defects, utilization of small-diameter ponderosa pine in glue-laminated timber, and examination of the material properties of woodfiber-plastic composites. The Lab maintains six areas of concentration: resource conservation, environmental research, sustaining ecosystems, social and economic vitality, foundation research, and public service.

The Lab has a number of research initiatives, several of which are relevant to California. Typical areas include expanding bio-based products and bioenergy; forest restoration and community economic revitalization through use of small-diameter and under-utilized species; and rural economic opportunities within the National Fire Plan.

The Lab is specifically involved in research conducted in Hayfork, California (FPL, 2002c). Hayfork is located in the Hayfork Adaptive Management Area in Trinity County. In an attempt to diversify its economic base, Hayfork hopes to develop value-added forest products from small diameter materials for such uses as flooring, furniture, and poles and posts. FPL research assists this effort in several ways, including examining the grades and characteristics of the lumber, refining kiln drying procedures, and developing appropriately scaled technologies that reduce manufacturing costs. See the online document Research Initiative: Forest Restoration and Community Economic Revitalization Through Use of Small-Diameter and Underutilized Species for more information (FPL, 2002c).

The USGS also maintains a significant presence in research and information activities involving California forest and rangeland. In recent years, its role has been strengthened to provide support for other bureaus within DOI, such as the FWS. During the last two FYs, USGS has been allocated approximately $130 million for cooperative topographic mapping, land remote sensing, and geographic analysis and monitoring. This funding will continue under the proposed budget for fiscal year 2003. Portions of these funds have been spent in California to improve watershed information in the North Coast (USGS, 2002a). USGS is also engaged in watershed research, including watershed ecosystem studies in Sequoia and Kings Canyon National Parks and other, smaller California watersheds. See the online document About the Water, Energy, and Biochemical Budgets Program for more information (USGS, 2002b).

In addition, the National Biological Survey (NBS), part of the USGS, coordinates the National Gap Analysis Program along with other efforts related to biodiversity. NBS also works with Cooperative Research Units around the country to conduct research on renewable natural resource issues (USGS, 2000). One such organization is the California Cooperative Fisheries Research Unit at Humboldt State University in Eureka.

Forest and rangeland research and information at the State level

State agency research is an assortment of information collection, monitoring, and actual research. The activities are described in Table 5.

Table 5. State agency forest and rangeland research and information

Agency	Department	Research and information
California Resources Agency	CDF	Vegetation mapping, forest assessment, rural population and land use, forest management, wildfire behavior
	DFG	Fish and wildlife inventories and management
	DOC	Farmland mapping; geological mapping and hazard assessment; soil conservation
	DPR	Recreation management and statistics
	CEC	Energy-related statistics and technologies, including renewable resources
	DWR	Water-related statistics, water use, water management, water conservation
California Environmental Protection Agency		
	ARB	Air quality statistics, air quality control technologies, air quality and transportation patterns
	SWRCB	Water quality and water rights statistics; watershed assessment
	California Department of Pesticide Regulation	Pesticide-related statistics
	CIWMB	Recycling and solid waste statistics; waste-related technologies
CDFA		Animal health and exotics tracking; border statistics, and weed/exotic data
UC system		Forestry and range science programs, veterinary school, and wide variety of topics
California State University (CSU) system		Limited research conducted by faculty or associated centers

Source: NMFS, 2001

Significant research related to forests and rangelands occurs within or through funding from DFG, DOC, and SWRCB and its RWQCBs. Over the years, DFG has conducted research related to wildlife, such as deer population dynamics, and fish, such as salmonid habitat and fish hatcheries. See the Assessment document Population Status of Native Species and the online document Final Report on Anadromous Salmonid Fish Hatcheries in California for more information (DFG and NMFS Joint Hatchery Review Committee, 2001). DFG has also been involved with habitat restoration activities. DOC, through CGS, provides geologic mapping information for various regions including forests and rangelands. See the online document Geologic Maps (CGS, 2000) or the NCWAP website for more information. The SWRCB along with RWQCBs have conducted or funded the collection of water quality information in a variety of ways. The Department of Water Resources has conducted a variety of research on water conservation, engineering, and use. ARB has conducted or funded research concerning pollutants and pollutant transport (especially ozone and fine particulate matter) relevant to forest and rangeland. The CEC supports research into renewable energy sources including biomass.

Twelve-year stand at Jackson Demonstration State Forest.

Research is also conducted by CDF through the State Demonstration Forest System and by FRAP. The State Demonstration Forest System is managed by CDF and is comprised of eight Demonstration State Forests covering 71,000 acres. The largest is the Jackson Demonstration State Forest (JDSF) near Fort Bragg in Mendocino County. JDSF shares

available funds with other state forests in order to finance competitive grants for research and demonstration and to conduct monitoring projects. Available funds include $600,000 annually to support research and demonstration projects and $150,000 to conduct monitoring activities and support infrastructure within the State Forest system. These resources, as well as the operating funds, are available through timber sales from the State Forest system, primarily JDSF. These funds are deposited into and allocated from the Forest Resource Investment Fund.

In 1997, administrators of the JDSF began revising its management plan as well as developing an HCP. Part of this plan will address research priorities. As part of this effort, former director Richard Wilson appointed an advisory committee that prepared specific recommendations for CDF on several of topics including research priorities. Examples included uneven-aged silviculture, impacts of harvesting on fish and wildlife, hardwood utilization, alternatives to herbicide use, utilization of wide stream buffers, and development of a scientific monitoring system. See the online document Jackson Demonstration State Forest Management Plan for more information (CDF, 2002). As part of its draft management plan, JDSF staff has identified a number of high research priorities that include topics related to fishery population dynamics and habitat, riparian zone wildlife habitat relationships, young forest stand management, watershed and vegetation management, and even and uneven-aged silvicultural systems.

In addition, the Caspar Creek Experimental Watershed Study is located on JDSF. It is a cooperative venture of CDF and the U.S. Forest Service that has been operating continuously since 1962. For the past 40 years, researchers have been studying the nature of hydrologic, erosion, and sedimentation impacts of logging operations. When formal cooperation began in 1962, the objective was to document hydrologic changes, erosion impacts, and sediment production resulting from road construction and logging second-growth forests. For the past 20 years, the two agencies have jointly evaluated potential cumulative watershed effects resulting from even-aged and uneven-aged silviculture, including responses in streamflow routing, sediment transport, water quality, fisheries, and other biological (algal and benthic macro invertebrate) communities. The Caspar Creek data represent the only long-term hydrologic information from managed second-growth conifer forests in the western U.S. Because of its long record and unique conditions, information from Caspar Creek will continue to be valuable to both the research and the land management communities as second- and third-growth forests are increasingly re-entered.

CDF FRAP fulfills its research and information development responsibilities through a combination of in-house work, contracting with universities, and close collaboration with the Region 5 USFS Remote Sensing Laboratory. In addition to meeting general forest and range land assessment responsibilities, FRAP has focused its work in these areas:

- Vegetation mapping and monitoring done in close collaboration with USFS;
- Fuels mapping and fire behavior modeling in support of the California Fire Plan and CDF's fire protection responsibilities;
- Watershed data and assessment approaches;
- Use of a wide range of census data in a spatial context to support analyses related to forest and range resources, fire protection, economics, and social considerations.

The role of universities in forest and rangeland research in California

The primary research programs directly related to State forestry issues are found within the UC system and the two State universities with accredited forestry schools—Humboldt State and Cal Poly San Luis Obispo. Most other faculty associated with the CSUS system conduct some research but do not have similar designated research responsibilities.

McIntire-Stennis Cooperative Forestry Program: The McIntire-Stennis Cooperative Forestry Program provides federal funds for forestry research at universities across the United States (Center for Forestry, 2002a). The program is administered by CSREES in partnership with the public and private sectors (CSREES, 2002). Funding can be used for certain categories of research, such as reforestation, watershed management, range management, recreation, and fire protection. Based on a formula, funds within California are designated for the UC system (Berkeley, Davis, and Riverside), Humboldt State University, and Cal Poly San Luis Obispo.

Within the University, most research and outreach related to forestry and rangeland occurs under programs of the University of California Division of Agriculture and Natural Resources (UCDANR). See the online document Divisionwide Programs for more information (UCDANR, 2002). The research is mostly associated with statewide programs, research and extension centers, and the natural reserve system. UCDANR contains nearly 1,100 research scientists and educators on three UC system campuses, nine field stations, and 64 Cooperative Extension specialists. The overall budget in fiscal year 2001 for agricultural research and teaching was roughly $25 million. Approximately $10 million was appropriated for teaching salaries and $15 million for research. Sixty percent of this $15 million financed research salaries.

A number of statewide university programs have been or are especially involved in forest and rangeland resource studies including the:

- University of California Agricultural Issues Center (AIC);
- Center for Pest Management Research and Extension;
- Center for Water Resources;
- UC Forest Products Laboratory;
- University of California Integrated Hardwood Range Management Program (UCIHRMP); and
- Wildland Resources Center and the Sustainable Agriculture Research and Education Program.

The AIC, FPL, and UCIHRMP have been especially important in the area of forest and rangeland-related research. The AIC at UC Davis has concentrated on studies related to various aspects of agriculture in California's urban landscape. These aspects have included land use, market economics, and international trade. UC Davis also maintains a distinguished veterinarian school that contributes most of the livestock-related research in the UC system.

UC Forest Products Lab (FPL) concentrates on biomass utilization of small non-timber trees, wood durability to improve the long-term performance of wood products, and ways to address the interaction of wildfire and urban landscapes. The lab also maintains the Service to Industry Program, providing services in wood building performance analysis as well as other diagnostic services related to wood materials. See the online document Service to Industry Program for more information (UCFPL, 2001a). During the last

five years, the budget for the lab has fluctuated between $1.5 million to $1.8 million. In fiscal year 2000-2001, the total budget was $1.75 million, $742,000 of which went to salaries, $506,000 to extramural projects, and $205,000 to the Service to Industry Program. Sources of internal funding are provided by UCDANR, whose budget is part of the UC Davis's overall budget. These are leveraged through external sources, gifts, and services to increase the total budget (UCFPL, 2001b).

The UCIHRMP examines questions related to hardwood rangeland resources in California. It also funds research for a variety of topics. Since UCIHRMP was established in 1986, 75 different research projects have been funded, resulting in over 150 scientific articles that have contributed to the understanding of hardwood rangelands (UCIHRMP, 2000). The program's annual State budget is $625,000. Approximately $200,000 is awarded annually to conduct research projects on priorities set by the program's advisory committee.

Several research field stations are administered by UCDANR. Two of these stations concentrate on research related to rangeland issues. These are the Sierra Foothill Research and Extension Center (SFREC) in Yuba County and the Hopland Research and Extension Center (HREC) in Mendocino County. SFREC is comprised of over 5,700 acres of oak woodland and annual grass rangeland. It maintains long-term databases related to the following topics: hardwoods and annual rangeland pasture use by cattle; beef cattle fertility, disease, and production levels; stream hydrology in managed watersheds; climate; and range forage yields. See the online document Home Page of the Sierra Foothill Research and Extension Center for more information (SFREC, 2002). HREC is comprised of 5,300 acres, and its research topics include a variety of items related to sheep husbandry, wildlife, and environmental management. See the online document Research: Current Project for more information (HREC, 2000).

Forestry research conducted by UC system campuses is coordinated by the Center for Forestry, part of UCDNAR and located at UC Berkeley. The budget for research and administration is approximately $1 million per year and is funded by the UC budget, timber sales, and endowments. Research projects, outreach and public education activities, and policy analysis are conducted through the Center by interdisciplinary teams of campus faculty, Cooperative Extension specialists and advisors, as well as other associated individuals. See the online document Forestry Research for more information (Center for Forestry, 2002b). The College for Natural Resources at Berkeley also maintains five forest properties, administered by the Center for Forestry. These include the Baker Forest in Plumas County, the Blodgett Forest Research Station in El Dorado County, Howard Forest in Mendocino County, Russell Tree Farm in Contra Costa County, and Whitaker's Forest in Tulare County.

Furthermore, the UC system maintains several cooperative research programs with federal agencies relevant to forest and rangeland resources. An example of this type of program is the California Gap Analysis Project, administered by the Biogeography Lab at UC Santa Barbara (UC Santa Barbara, 2002). This project is part of the National Gap Analysis Program directed by the USGS Biological Resources Discipline (BRD). See the online document National Gap Analysis Program for more information (BRD, 2002). The national program concentrates on biodiversity protection.

Gap Analysis: The term "Gap Analysis" refers to analysis of the management status of plant communities and vertebrate species (as well as the richness of vertebrate species) by comparing biological distribution data with existing biological reserves. Geographic Information System (GIS) maps are developed at a 1:100,000 scale in order to identify landscapes that contain large numbers of potentially unprotected vegetation types and vertebrate species. More detailed studies are then possible to develop methods that fill "gaps" in the reserve network.

UC Santa Barbara also hosts the National Center for Ecological Analysis and Synthesis (NCEAS) (NCEAS, 2002). Partly funded by the NSF, NCEAS concentrates on studies that relate to fundamental and applied problems in ecology, including techniques that involve mathematical modeling, dynamic simulation, and digital mapping of complex ecological phenomena.

Water research is coordinated and funded by the California Centers for Water and Wildland Resources located at UC Riverside. The organization allocates about $1.1 million annually in research funding to faculty investigators on the nine UC system campuses (New Mexico Water Resources Institute, 2001).

Another research asset is the UC Natural Reserve System (UCNRS). It includes 34 reserves comprised of over 130,000 acres across 12 ecological regions in California. Twelve of these areas have or will have the ability to support long-term research projects and multi-week field courses remote from campus services. These reserves are protected from development and are available for university-level instruction, research, and public outreach. See the online document Home Page of the University of California Natural Reserve System for more information (UCNRS, 1999). Examples of research conducted in the UCNRS include the formulation of HCPs at the Canyon Desert Center in order to sustain the California Desert, and the development of a sustainable approach in the Northern Coast range with the Blue Ridge Berryessa Natural Area Conservation Partnership. See the online document Natural Reserve System Helping in Regional Planning Efforts for more information (Booth, 2002).

Within the CSU system, four campuses maintain a history of agricultural research, education, and technology transfer, a portion of which relates to livestock. These include California Polytechnic State University at San Luis Obispo, CSU Fresno, California State Polytechnic University at Pomona, and CSU Chico. Cal Poly San Luis Obispo also maintains a fully accredited forestry program, as does Humboldt State University. Both conduct some forestry and rangeland-related research.

Agricultural research initiative: In 1999, Governor Gray Davis authorized $5 million per year to be allocated for agricultural research and extension in eight high priority areas. These areas were collaboratively delineated by the agricultural industry and federal, State, and local governmental agencies and interest groups. They include: agricultural business management; biodiversity management; biotechnology; food processing, safety, nutrition, and new product development; irrigation management and technology; natural resources management; production management systems and cultural practices; and public policy development (California Polytechnic State University, San Luis Obispo, 2002). The CSU system provided the funding for the initiative, and resources were allocated to each of the four agricultural colleges.

Research conducted at Cal Poly San Luis Obispo occurs within the College of Agriculture. Research related to forestry and rangeland occurs within the Cal Poly San Luis Obispo, Department of Natural Resources Management (NRM) (NRM, 2002). NRM operates a fully accredited forestry program and two

institutes, the Urban Forestry Ecosystems Institute (UFEI) and the Coastal Resources Institute (CRI) (UFEI, 2002; CRI, 2002). NRM also owns and maintains Swanton Pacific Ranch (2002) in Santa Cruz County, a research and teaching location for both forest and rangeland management.

CRI uses a network of staff and students in cooperation with the many colleges of Cal Poly San Luis Obispo to conduct research in the central coast area. Examples of these studies include a report on the population differentiation of spring and fall Chinook salmon and an environmental report on California's hatchery program (CRI, 2002).

UFEI concentrates on issues related to the management of urban forests. Institute staff conduct applied research, extension and technology transfer, and community outreach. Examples of applied research include elements of sustainability in urban forests, modeling the value of tree aesthetics in an urban setting, and development of tree volume equations for tree species in urban settings (UFEI, 2002).

The College of Agriculture at Cal Poly San Luis Obispo maintains a well-known program, including a strong animal science department. While there is extensive knowledge transfer through teaching and projects, the only livestock-related research arm is the Dairy Products Technology Center.

Similarly, rangeland-related research occurs through the College of Agriculture at CSU Chico. Topics have included the effects of seedling shelters on blue oak seedlings and control of starthistle (Chico College of Agriculture, 2002). The Department of Animal Science of the College of Agricultural Sciences and Technology at CSU Fresno also conducts teaching and research into beef cattle (College of Agricultural Sciences and Technology, 2002).

Humboldt State University maintains a fully accredited forestry program, as well as a substantial program in forestry and fish-related sciences through its College of Natural Resources and Sciences. It also has a variety of research programs related to aspects of forestry. These include the Forest Science Project and the Institute for Ecological Tourism (Forest Science Project, 2002; Institute for Ecological Tourism, 2002). The Forest Science Project conducts research related to regional coho salmonid surveys and stream temperature, while the purpose of the Institute for Ecological Tourism is to develop this new industry. Forest and rangeland research is conducted on several properties, including the 4,500-acre Galbreath Ranch. See the online document Resources and Facilities Available to HSU Students for more information (Department of Forestry and Watershed Management, 2002).

Forestry research conducted by the California forest industry

During the last decade, much of the research conducted by the California forest industry has concentrated on improving land management techniques and facilitating governmental permit requirements. There have been many approaches including development of environmentally sensitive timber harvesting methods, the refinement of stream restoration techniques, improved forest inventory efforts, achieving greater detail in watershed analysis, and completing wildlife surveys and fish assessments needed to meet the permit requirements of federal and State agencies. Furthermore, the industry has invested in enhanced computer modeling, GIS services, and field monitoring of management actions. The results

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of these studies are being used to determine the status of resources on company lands, to prepare and discuss management options with permitting agencies and the public, and to change plans that reflect the results of earlier decisions.

This research is often collaborative, as is the case with NMFS or DFG in matters related to fish or with FWS in matters related to non-fish species. This collaboration has been accelerated as timber companies work to develop HCPs under the federal Endangered Species Act (ESA) or to meet forest certification requirements such as those of the Forest Stewardship Council or the Sustainable Forestry Initiative of the American Forest and Paper Association. The frameworks of both HCPs and various certification schemes require more detailed information for preparation of documents and active monitoring.

Examples of research conducted by forest products corporations exist both in the North Coast and the Sierra. The Pacific Lumber Company (PALCO), Simpson Timber Company, Mendocino Redwoods Company (MRC), and Sierra Pacific Industries maintain ongoing research efforts in the North Coast. The Collins Pine Company and Sierra Pacific Industries conduct various research-related programs in the Sierra.

In March 1, 1999, PALCO signed an agreement with the State of California and the federal government to sell the Headwaters Forest to the public. As part of this historic agreement, the company developed an HCP to protect fish, wildlife, and water quality on their timberlands. In addition to research completed during the plan's formulation, PALCO agreed to conduct further watershed assessments and to maintain an ongoing program that monitors the status of selected species including the marbled murrelet, northern spotted owl, coho salmon, Chinook salmon, steelhead trout, and coastal cutthroat trout. See the online document Using the Best Science Available to Make Decisions—Today and Tomorrow for more information (PALCO, 2000a). The watershed analysis process utilizes teams of independent experts, PALCO staff, and representatives from State and federal agencies in order to assess watershed condition and develop site-specific protection measures. See the online document Protecting Birds, Fish and Animals as Well as the Places They Live for more information (PALCO, 2000b).

PALCO has also conducted fisheries restoration projects since the early 1970s. In 1992, PALCO signed a cooperative agreement with DFG to collaborate on fish habitat restoration efforts. Projects under this agreement have occurred on the Eel and Van Duzen rivers and involve a variety of activities including stream and habitat analysis, biological sampling and fish counting, watershed erosion and sediment yield analysis, and substrate analysis (PALCO, 2001).

Source: PALCO, 2000c.

Forest management research conducted by the Simpson Timber Company has concentrated on assessment of its timber harvesting operations regarding unstable slopes, fish, and wildlife. These studies have led to improved road design and construction practices and the increased use of cable logging and hydraulic loaders. See the online document Resource Management and Protection for more information (Simpson Timber Company, 2001a). Simpson was a pioneer in applied wildlife research, hiring its first wildlife biologist in 1990 to

address issues related to the northern spotted owl. Presently, its wildlife research program has expanded in order to address additional fish and wildlife species, including the dusky-footed woodrat, the Pacific fisher, the red tree vole, and various amphibians (Simpson Timber Company, 2001b). In 1992, Simpson completed an HCP that protected the northern spotted owl. Currently, the organization is finalizing an HCP that protects salmonids as well as other species. Furthermore, the company has developed an improved seedstock at its forest nursery near Korbel. This resource is both used on company lands and sold to other forest landowners (Simpson Timber Company, 2001b).

MRC also conducts research relevant to its operations, including wildlife surveys, fish habitat monitoring, and watershed analysis. In 1999, MRC conducted forest carnivore surveys on sections of its property. Currently, it is developing a northern spotted owl management plan using radio telemetry data and is collecting statistics on the breeding habits of cavity nesting birds on its property. Its watershed assessment work involves collection of baseline stream conditions, development of a comprehensive road inventory to prioritize restoration work, limiting harvest activities, and monitoring long-term trends (MRC, 2002a). A comprehensive inventory and database of all roads on MRC lands is schedule for completion by 2004. During 2001, MRC conducted a pilot project on its lands in Sonoma County regarding alternative watershed evaluation processes under consideration for Forest Practice Rules (MRC, 2002a). MRC also collaborates with other organizations in conducting extensive stream restoration work (MRC, 2002b).

Sierra Pacific Industries, California's largest forest products corporation, also supports an active research program. Company research publications relate to water quality, fish, and wildlife. Specific wildlife studies involve habitat needs of the Pacific fischer and the pine marten, snag management for cavity nesting birds, and analysis of the nesting success of landbirds in order to evaluate the biological effects of forest management practices. See the online document Our Forests – Research and Monitoring for more information (Sierra Pacific Industries. 2002).

The Collins Pine Company (Almanor Forest) also possesses an extensive history of conducting research on their property. This history includes the development of a system 50 years ago to identify trees at risk from forest insects and disease and conduct detailed forest inventory work. In recent years, the company has been a leader in the use of forest certification as a management and marketing tool (The Collins Companies, Inc. 2002).

Role of non-profits

Non-profit institutions are also involved in California forest and rangeland research. Foundations provide funding for projects associated with a variety of individuals and entities, including other foundations. Most of this activity occurs through the funding of proposals that are within the scope of a foundation's purpose or interest. The majority of these grants are related to policy, land conservation and habitat preservation, land acquisition, and the social aspects of forest and rangeland.

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A few non-profits, such as The Nature Conservancy, own and manage forests and rangelands in California. For the most part, these organizations concentrate on land conservation and habitat preservation. Likewise, their research involves conservation planning and acquisition strategies. Present research of The Nature Conservancy involves identification of ecoregions, conservation targets, and other factors. In California, these efforts are concentrated in the North Coast ecoregion in which five focus areas have been identified involving 90 portfolio sites. Research emphases include encouraging local organizations to support The Nature Conservancy's priorities and the development of multi-site conservation strategies for timber and vineyard lands in the region (The Nature Conservancy, 2002).

Cosumnes Preserve is a project of The Nature Conservancy. Rice and bean fields along the river have been transformed into oak savannas and wetlands. More than 1,500 acres of new wetlands invite thousands of wintering waterfowl.

In recent years, the largest non-profit organization awarding grants for environmental conservation has been The David and Lucile Packard Foundation. The foundation emphasizes habitat and land preservation. In 1998, the foundation announced that it would invest $375 million in environmental organizations that possessed one or more of the following three interests: protecting critical habitats and biological diversity; promoting sustainable resource use; and advancing science for conservation. See the online document Packard Foundation Dramatically Increases Its Commitment to the Environment for more information (The David and Lucile Packard Foundation, 2000a). The basis for the foundation's program is the Conserving California Landscapes Initiative designed to conserve at least a quarter million acres of natural systems in the Central Coast, the Central Valley, and the Sierra Nevada. The plan mainly involves groups such as The Nature Conservancy, Trust for Public Land, and other land trusts. A portion of this funding is reserved for planning, policy, capacity building, and restoration and stewardship necessary to achieving the foundation's goals. From 1999 through 2001, over $94 million was allocated for the initiative. See the online document 2001 Grants for Conservation: California and the West: Conserving California Landscapes Initiative for more information (The David and Lucile Packard Foundation, 2000b). The foundation also sponsors a Sustainability Science Program through which it intends to conduct natural and social science research important to its conservation policies (The David and Lucile Packard Foundation, 2002).

A similar non-profit is The William and Flora Hewlett Foundation. See the online document Environment Guidelines for more information (The William and Flora Hewlett Foundation, 1998). The foundation maintains an environmental program that was largely designed to promote sustainable metropolitan growth and environmental management in rural communities of the western United States. Grants under this program have been awarded to studies addressing a wide variety of issues in public and private land-use management such as grazing, mining, logging, and urban sprawl. In recent years, the program's primary budget has been over $13 million. Because of expanded priorities including conservation issues in California, the budget increased in 2001 by an additional $10 million (The William and Flora Hewlett Foundation, 1988). Under its program for Environmental Management in Rural

Communities, the Foundation awarded approximately $500,000 in grants to organizations with concentrations in forest or rangeland issues.

Another non-profit organization is The James Irvine Foundation. See the online document Home Page of the James Irvine Foundation for more information (The James Irvine Foundation, 2002a). The Foundation operates several programs including the Sustainable Communities Program. Its goal is to protect and improve quality of life for Californian residents in the midst of State growth (The James Irvine Foundation, 2002b). Rather than concentrate on habitat or land preservation, the foundation supports "human habitats" or groups that operate at the intersection of the economy, the environment, and social equity. Priorities have included brownfield redevelopment, healthy forests and communities, rangeland preservation, and urban land use planning.

As part of its Sustainable Communities Program, the foundation has developed the Land Use Initiative that addresses the challenge of fragmented land use planning (The James Irvine Foundation, 2002c). Its established goals are to enable specific communities to advocate and promote change that will result in sustainable land use and to create statewide support for the issue (The James Irvine Foundation, 2002c).

Foundations often "partner" in grant making efforts, such as The David and Lucile Packard Foundation funding of The Nature Conservancy activities. In certain cases, foundations may also pursue diverse, but compatible approaches to issues. For example, the James Irvine Foundation might concentrate on land use planning efforts that are compatible with the biodiversity goals of The David and Lucile Packard Foundation's California Landscapes Initiative. At the same time, the James Irvine Foundation could pursue growth management initiatives consistent with the intent of the environmental program of The William and Flora Hewlett Foundation Environmental (ibid).

Research funding for forest and rangeland-related research

There is no current estimate of the amount of funding spent on forest and rangeland research in California. One source of information regarding agricultural and forest-related research is the Current Research Information System (CRIS) maintained by CSREES. This database collects information from a variety of sources, including federal agencies, State agricultural experiment stations, and forestry schools. It includes information about federal, State, and non-federal research expenditures and indexes them into several categories, one of which is subject matter. The most recent information provided by the USFS in the CRIS database extends only to 1997. Based upon selected subject categories that relate all or in part to forest and rangeland resources in California, research in these areas accounted for slightly less than one fifth of all research for the State tracked by the US Department of Agriculture. Reported expenditures for 1991, 1994, and 1997 are shown in Table 6, along with estimated expenditures for 2001.

Table 6. Funding levels for forest and rangeland research, 1991, 1994, 1997, and estimated 2001 (million dollars*)

	1991		1994		1997		2001**	
	Science years	Budget*	Science years	Budget *	Science years	Budget *	Science years	Budget *
Watersheds	4.9	1.3	3.4	1.0	6.7	2.3	7.8	3.4
Recreation	8.8	1.8	7.1	1.4	5.8	1.2	1.4	.6
Trees, forest products	80.1	19.4	59.6	16.9	57.9	17.2	23.3	8.9
Range	10.7	2.3	9.6	3.0	11.8	4.0	8.8	3.3
Wildlife and fish	32.6	13.1	34.2	13.0	27.8	11.9	18.0	11.7
Beef cattle	14.0	3.8	17.2	5.1	26.5	5.1	20.8	7.9
Sheep and wool	5.9	1.3	5.0	1.6	9.2	2.7	8.1	2.7
Subtotal for selected categories	157	43	136.1	42	187.2	44.4	---	***54.6
Total California	869.5	228.3	754.1	245.6	701.1	267.5	738.5	342.4
Percentage of California total	23	18	18	17	26	16	----	19.8

***Does not include data from USDA, USFS.*
****Includes an estimated $16.1 million for USFS, PSW.*

Source: CSREES, USFS, PNW, PSW, 2001

Areas of research priority

Typically, research subject matter relates to the interests of both the researcher and the entity funding the research. The federal government is the primary source of funding for forest and rangeland-related research. Prior to the 1990s, agencies within the federal government often did not coordinate their research priorities or develop approaches leading to results that would fulfill their mandates.

Research subject areas and research priorities have evolved over the years. They often reflect topics that capture public attention, such as wildfire, endangered species, or Sudden Oak Death. The level of funding and program direction may both change quickly.

The priorities of rangeland research have been dominated by concerns regarding issues related to hardwood rangelands and the improvement of livestock health. In both cases, research and extension (outreach) are often interconnected.

The UCIHRMP was created at UC in 1986 in order to respond to the issues of hardwood rangelands. Early research concentrated on questions related to oak regeneration and to the interactions between range management and hardwood forests and wildlife. Subsequent research under UCIHRMP and associated programs increasingly emphasized the impacts of range management on water quality. Research topics in 2000-2001 included sustainability, wildlife, water quality and riparian management, the fragmentation of hardwood range habitat, fire ecology and effects, and monitoring of hardwood rangeland resources (UCIHRMP, 2001).

Topics associated with an increase in livestock production include improved livestock health. For example, a number of research projects exploring cattle disease are in progress at the UC Davis School of Veterinary Medicine. See the online document Cattle Disease Research Projects for more information (UC Davis School of Veterinary Medicine, 2000).

Relatively little livestock-specific research involving production and marketing transpires in California. The University of California Cooperative Extension (UCCE) provides links to this type of research conducted elsewhere (UCCE, 1999). However, AIC occasionally analyzes larger policy

questions involving the livestock industry (AIC, 2002). The work of the Center varies, but in recent years has concentrated on the impact of urbanization and international markets on California agriculture.

In the 1980s, the BOF's committee on research identified 12 critical areas of research including cumulative watershed effects, vegetation and pest management, landowner rights and responsibilities, riparian zone management, land fragmentation, recreation, sediment yield, uneven-aged silvicultural systems and monitoring, wildlife habitat, forest and rangeland education, public attitudes, and multi-resource inventories and database development.

In 1989, the UC Wildland Resource Center conducted three workshops in order to determine forestry research needs. It identified a range of topics including the following: 1) providing technology to improve the management of stream channels and aquatic habitats; 2) addressing cumulative watershed effects and sediment in streams; 3) the improvement of mapping and inventories; 4) management strategies relating to the practice of forestry near urban areas; 5) superior management and definition of fish and wildlife habitat; and 6) improving techniques used to identify geological hazards and manage unstable watersheds.

In 1994, a poll concerning research needs was conducted at the Coast Redwood Forest Management/Silviculture Conference. Topics included the following: 1) the dynamics of group selection; 2) management of riparian and aquatic resources; 3) demonstration of sustained uneven-aged forestry; 4) spatial dynamics of stand structure; 5) coppice management habitat and wildlife relationships; 6) documentation and synthesis of existing information on coast redwood forests; and 7) specific studies in JDSF.

From 2000-2002, intense public interest has existed regarding the control of pitch canker and SOD. See the Assessment document Forest Pests and Diseases for more information. Legislation passed and signed into law in 1998 (SB 1712, chapter 713, 1998) (Legislative Council of California, 1998) provided CDF with $2.1 million in funding over a six-year period for pitch canker research, control, and public education. Approximately a fifth of the funding is allocated for studies designed to advance the understanding of disease, vector, and pine host relationships with respect to appropriate management of pine forests throughout the State (FRAP, 2002b). At the request of Representatives Woolsey and Thompson, the USDA fiscal year 2001 budget contained $3.5 million to address issues related to SOD. Congress is also considering the Sudden Oak Death Syndrome Control Act of 2002 (U.S. Government Printing Office, 2002b). See the online document Home Page of the California Oak Mortality Task Force for more information (California Oak Mortality Task Force, 2002). The bill would direct the Secretary of Agriculture to initiate research, monitoring, management, treatment, and outreach activities relating to SOD syndrome. It would authorize $52.5 million in funding over a six-year period, $10.5 million of which would be allocated for research, monitoring, and treatment (U.S. Government Printing Office, 2002b).

Other areas of forestry-related research are currently being emphasized as well. These are summarized in Table 6.

Table 6. Forestry-related research

Topical area	Major players
Exotic weeds and pests (preventing entry, spread, and control)	Cooperative efforts, strong UC role
Hardwood ecosystems and land conversion	UCIHRMP
Wildlife habitat and population dynamics, particularly information necessary to formulate HCPs	USFS, private industry, FWS, UC
Riparian habitat and fish population dynamics, particularly information necessary to formulate HCPs	Private industry, DFG, NMFS
Identification of unstable areas and related geologic information	USGS, CGS
Improved forest inventory data and spatial information	USFS, CDF, private industry
Watershed assessment, particularly regarding the causes and control of pollution in waterbodies not satisfying water quality standards	SWRCB, RWQCBs, private industry, UC
Interactions of urban populations and forests	USFS, UC
Air quality related to ozone and fine particulant matter	ARB, EPA, USFS
Wildfire impact, control, and risks	USFS, CDF
Forest genetics	USFS, private industry
Renewable Energy Sources – biofuels and biomass	DOE, private industry
Improved wood utilization and forest product development	USFS, UC, private industry
Forest policy, including methodology development that measures and integrates environmental and social costs and benefits into markets and public policies	USFS, UC, non-profits

Source: FRAP, 2002a

Observations and conclusions

Over the past decade, there have been significant increases in the number of programs and dollars oriented towards information collection, monitoring, and research related to forest and range resources. Baselines of information still need to be established from which to conduct condition monitoring. Many programs involve implementation and effectiveness monitoring. However, many areas require validation monitoring efforts in order to test whether or not the assumptions underlying management actions are valid.

There has been an increasing diversity in the variety of agencies financing the research and information. Paradoxically there seems to be less agreement on how to use the research and information to define and guide sustainable forest and rangeland uses. The increased involvement of regulatory agencies responsible for changing standards in areas such as water quality, public health and safety, and endangered species habitats have made it more difficult to coordinate long term information collection, monitoring, and research.

The context of forest and rangeland resource decisions also have broadened to reflect the recognition that society and ecosystems are complex, unpredictable, and interconnected. Monitoring and research are

fundamental tools used more and more to manage this uncertainty. However, they are best used as part of a process that allows individuals and communities to resolve conflicts, manage multiple values and institutions, share information, and collaborate to solve common problems.

One example of this fact is the 2001 report of the University of California Committee on Cumulative Watershed Effects, which provided a provocative assessment on the scientific state of knowledge about cumulative watershed effects. The committee proposed a risk-based modeling approach to assess cumulative watershed effects since they concluded that the threshold between impact and no-impact is not always discrete or measurable. They described how new modeling techniques could be employed to achieve a better understanding of natural processes at larger scales. They also suggested that the situation requires close collaboration among the various agencies and major stakeholders who both collect information and control future management interventions.

Another example is research over the last decade about the role of fire in California's ecosystems. This research has focused on understanding fire effects on habitat characteristics, management policy related changes in fuel structure, and alternative strategies to balance ecological needs with social and economic assets at risk from fire. There has been significant federal-state collaboration to improve the accuracy and spatial resolution of assessing the basic fire environment for fuels, weather, and modes of fire spread across all lands, irrespective of ownership and fire protection responsibility. As more of the new research is tied to the agencies responsible for fire protection, there is a greater effort towards integrating research, information collection, and monitoring. One example of integrating science with management has come out of the Sierra Nevada Ecosystem Project (SNEP) and the follow-up Sierra Nevada Framework for Conservation. SNEP determined that interactions between fire risks to people, habitat, and long-term forest health form the basis for policy, implementation, and monitoring. This process assures that research continues to offer feedback mechanisms as insight is gained in the complexity of fire as a landscape level phenomenon.

Adaptive Management Areas (AMAs) as an experiment in research emphasizing social context: The NWFP designated 10 areas of the Pacific Northwest, including Northwestern California, as AMAs. The purpose of these areas was to experiment with adaptive approaches to land management. Management actions were to be based on an ongoing process of planning, monitoring, evaluation, and adjustment. The goal of management was to maintain and improve the health of the ecosystem as judged by standards such as biodiversity, health of riparian and aquatic resources, and improving conditions for sensitive wildlife species. Change of management was associated with commonly accepted measures and monitoring that reflected the best available science.

Scientists were appointed to administer projects on each AMA. Part of their role was to interact closely with other scientists, managers, and citizens while supervising the area. The theory was that the practice of consistent interaction between these parties was more likely to address the complexity, uncertainty, and perceptions of risk regarding work across larger landscapes. This approach emphasizes dialogue as integral to the ongoing process of social and ecological learning. Furthermore, the utilization of common approaches and scales of analyses is critical.

In 1999, the budget for the AMA program was terminated, effectively ending research efforts that required specific agency support of adaptive management. Some scientists still include the adaptive management philosophy in their research programs (Graham and Kruger, 2002).

In early 1998, federal agencies involved in the NWFP published a draft entitled "Strategic Research Plan to Support Implementation of the Pacific Northwest Forest Plan." It identified the areas of research necessary to meet the broader objectives of the plan and provided a framework for interagency coordination. Presently, research and monitoring are coordinated through the Regional Ecosystem Office created to implement the NWFP. Federal agencies have continued to meet as part of the Regional Interagency Executive Committee (REIC) (Regional Ecosystem Office, 2002). The RIEC consists of regional directors from the federal land management, regulatory, research, and various other agencies located in Northern California, Western Oregon, and Western Washington. In April 2002, RIEC initiated discussions regarding the issue of adaptive management and methods of incorporating research findings into decision-making.

The need to temper research with social context as realized in the NWFP appears to be valid. Both in California and other regions, problems develop when local citizens familiar with an area encounter the perception that only "experts" possess the required knowledge. An example of this scenario is evident through the experiences of the Quincy Library Group. See the Assessment document Institutional Framework: Governance Shifts during the 1990s for more information. While reliance on experts can be helpful in the arena of state or national politics, solutions are often best achieved through collaboration among scientists, citizens, and agency managers at the local level. Furthermore, stakeholder involvement promotes the development and application of a more robust knowledge initially derived from policies and project-based research results (Stankey and Shindler, 1997). See the Assessment document Institutional Framework: Governance Shifts during the 1990s for more information.

There is a need to address questions at the ecosystem level more effectively. However, the ability to do so is limited. The most effective research framework would include multiple scientific disciplines, and would be able to learn from and share results of its research with the larger community. Yet, existing institutions can make this difficult. These include: 1) the tendency to reward independent work and academic publication over collective, interdisciplinary work published in more informal arenas; 2) the structure and reliability of research funding; 3) agency operating procedures; and 4) limited stakeholder involvement. Scientists themselves differ in their ability to think holistically or outside the range of their traditional training.

Perhaps both in response to the need to think more holistically and to develop common understandings of problems, the "watershed" has emerged as the basic unit of analysis of forest and range ecosystems. Watershed assessment refers to systematic evaluation of the environmental health of landscapes and associated stream systems, with a particular focus on aquatic ecosystems and the way in which they are affected by hillslope processes and land use. A range of entities—from individual landowners to state agencies to large stakeholder groups—has been increasingly conducting watershed

assessments at a number of scales, from relatively small urban creeks to large systems such as the American River.

There is also a need to develop better methodologies that measure and integrate environmental and social costs and benefits into markets and public policies. In the case of public policies, the basic legal structure to measure (either quantitatively or qualitatively) social costs and benefits is established by the California Environmental Quality Act and rulemaking procedures set out by the Office of Administrative Law. This requires environmental impacts and economic impacts to be spelled out in environmental analyses, public hearing documents, and rulemaking records. At the policy level, values are balanced by boards, commissions, and other decision makers.

To some degree, methodologies also have been researched and applied to measure and integrate environmental and social costs and benefits into markets. One example of this is air pollution offsets. Another is the recent passage of SB 1078 which requires that 20 percent of the State's electrical supply mix be met from renewable energy resources by 2017 (called Renewable Portfolio Standard). A third is an on-going effort by the California Energy Commission to associate renewable energy investment decisions with potential public benefits such as a decline in wildfire risk or air pollution. A fourth example is the Ranching for Wildlife Program of the Department of Fish and Game where ranchers are provided increased hunting allocations in return for habitat improvement.

In so far as the Montreal protocol criteria and indicators were used in this Assessment, there is not always sufficient information to establish measures and trends. In some cases, this difficulty is inherent in the ambiguity or context of the indicator, especially as it is applied to the sustainability of rangelands. In other cases, such as the condition of private rangelands or interactions of land use with fish and wildlife populations dynamics, information may be scanty or lacking.

Another area of concern is how to understand the impact of technological change on how Californians view and use forest and rangelands. At a broad scale, developments in communications and jobs based on new technologies affect settlement and commute patterns. New technologies are being applied to air, water, and waste pollution control. At a smaller scale, the forest products and range industries are affected by:

- new approaches in building materials;
- use of genetics for improved trees, animals, and meat;
- utilization of information technologies such as computer mapping and spatial analysis techniques; and
- new processes to convert woody biomass and cellulose into fuels from bio-refineries and into other bio-based products, such as sugars or extractives.

The ability to assess the socio-economic consequences of these changes is highly varied. At one level, for example, economic models are used to predict the impact of new technologies on jobs and income. At another extreme, it is much more difficult to resolve social issues related to increased use of genetically manipulated plants and animals.

The difficulty of predicting how society will react to new technologies and their impact on the environment has increased the importance of research into creation of "social capital." The meaning of social capital is the ability of individuals and communities to resolve conflicts, address multiple values

and institutions, share information, and collaborate to resolve common problems. As social capital is developed, an environment conducive to managing uncertainty and change is created.

Another issue is that most of the research and information used in California for range and forest resources are not put in a national accounts framework. This makes it more difficult to calculate the true economic costs of growth or to compare these costs to those of other nations. Historically, depletion of forest and range resources in California has been associated with factors such as the harvest of timber in excess of growth, use of forage beyond the carrying capacity of the range, and hunting, fishing and other practices that destroy habitat and threaten sustainable populations of species. California has tracked rates of harvest and levels of fishing, hunting, and other uses that affect habitat. Significant effort also has been devoted to measuring forest inventories, biodiversity, and related factors.

Replenishment of range and forest resources is being accomplished by a mix of programs that includes purchase of reserves, restoration, and incentives to private landowners for improved stewardship. Regulatory mechanisms, such as forest practice rules and water quality standards limit further degradation (depletion). However, for a variety of reasons, it is difficult to assess if replenishment and regulatory efforts ultimately will be successful in maintaining forest and range sustainability. Research on the interaction and overall success of these approaches is both complex and badly needed. It is the underpinning of forest and range sustainability.

Glossary

AIC: University of California Agricultural Issues Center.

AMA: Adaptive Management Area.

anadromous salmonids: Salmon species which use both fresh waterbodies and oceans for various life stages.

AQMD: Air Quality Management District.

ARB: California Air Resources Board.

ARS: Agricultural Research Service.

biofuels: Fuels made from cellulosic biomass resources. Biofuels include ethanol, biodiesel, and methanol

biomass: Plant material that can be converted into fuel.

BLM: U.S. Bureau of Land Management.

BOF: California State Board of Forestry and Fire Protection.

BRD: USGS Biological Resources Discipline.

brownfield: A piece of industrial or commercial property that is abandoned or underused and often environmentally contaminated, especially one considered as a potential site for redevelopment.

CDE: California Department of Education.

CDF: California Department of Forestry and Fire Protection.

CDFA: California Department of Food and Agriculture.

CEC: California Energy Commission.

CGS: California Geological Survey.

CIWMB: California Integrated Waste Management Board.

coppice: A thicket or grove of small trees or shrubs, especially one maintained by periodic cutting or pruning to encourage suckering.

CRI: Coastal Resources Institute.

CRIS: Current Research Information System.

CSREES: U.S. Cooperative State Research, Education, and Extension Service.

CSU: California State University.

DFG: California Department of Fish and Game.

DOC: California Department of Conservation.

DOE: U.S. Department of Energy.

DOF: California Department of Finance.

DOI: U.S. Department of the Interior.

DPR: California Department of Parks and Recreation.

DWR: California Department of Water Resources.

EPA: U.S. Environmental Protection Agency.

ESA: Endangered Species Act.

FPL: U.S. Forest Products Laboratory.

FRAP: California Fire and Resource Assessment Program.

FWS: U.S. Fish and Wildlife Service.

FY: fiscal year.

GIS: Geographic Information System.

HCP: Habitat Conservation Plan.

HREC: Hopland Research and Extension Center

JDSF: Jackson Demonstration State Forest.

Montreal Process: A scientifically rigorous set of criteria and indicators used to measure forest management and sustainability.

MRC: Mendocino Redwoods Company.

NASA: National Aeronautics and Space Administration.

NBS: National Biological Survey.

NCEAS: National Center for Ecological Analysis and Synthesis.

NMFS: National Marine Fisheries Service.

NOAA: National Oceanic and Atmospheric Administration.

NPS: U.S. National Park Service.

NRCS: U.S. Natural Resources Conservation Service.

NRM: California Polytechnic State University, San Luis Obispo, Department of Natural Resources Management.

NSF: National Science Foundation.

NWFP: Northwest Forest Plan.

PALCO: Pacific Lumber Company.

PNW: Pacific Northwest Research Station.

PSW: Pacific Southwest Research Station.

rangeland: Any expanse of land not fertilized, cultivated or irrigated that is suitable, and predominately used for, grazing by domestic livestock and wildlife. These include the Conifer Woodland, Hardwood Woodland, Shrub, Grassland, Desert land cover types along with and some habitats within the Wetland and Hardwood Forest land cover classes.

RIEC: Regional Interagency Executive Committee.

riparian: Relating to or located on the banks of a river or stream.

riparian area: Transition zone between a stream's edge and the dryer uplands.

RWQCB: Regional Water Quality Control Board.

salmonids: Salmon species.

silviculture: Generally, the science and art of cultivating (such as with growing and tending) forest crops, based on the knowledge of silvics. More explicitly, the theory and practice of controlling the establishment, composition, constitution, and growth of forests.

SFREC: Sierra Foothill Research and Extension Center.

social capital: The ability of individuals and communities to resolve conflicts, address multiple values and institutions, share information, and collaborate to resolve common problems.

SOD: Sudden Oak Death.

stand: A group of trees sufficiently uniform in composition, age, and/or condition as to form a management entity and distinguishable from adjoining groups of trees.

substrate: The material or substance on which an enzyme acts.

succession: Process of vegetational development whereby an area becomes successively occupied by different plant communities of higher ecological order.

SWRCB: California State Water Resources Control Board.

UC: University of California.

UCDNAR: University of California Division of Agriculture and Natural Resources.

UCCE: University of California Cooperative Extension.

UCIHRMP: University of California Integrated Hardwood Range Management Program.

UCNRS: University of California Natural Reserve System.

UFEI: Urban Forest Ecosystems Institute.

uneven-aged: Silvicultural system in which individual trees originate at different times and result in a forest with trees of many ages and sizes; stands where less than 70 percent of the tree stocking falls in three adjacent 10 year age classes.

USACE: U.S. Army Corps of Engineers.

USDA: U.S. Department of Agriculture.

USFS: U.S. Forest Service.

USGS: U.S. Geological Survey.

watershed: The land area drained by a particular stream course.

Literature cited

Baker, Dave, Liang Hsin, and Mario Mamone. 2000. Result of the FY 2000 Implementation Monitoring Program. Regional Implementation Monitoring Team. Web site accessed October 10, 2002. http://www.reo.gov/monitoring/implementation/reports/02jun04-fy2000rept3.pdf.

Booth, Jerry. 2002. Natural reserve system helping in regional planning efforts. ANR report. Vol. 15, No. 7: 3. Web site accessed October 16, 2002. http://danr.ucop.edu/anr-report/report02/rptpdf02/january-2002.pdf.

California Department of Fish and Game (DFG) and National Marine Fisheries Service (NMFS) Joint Hatchery Review Committee. 2001. Final report on anadromous salmonid fish hatcheries in California. California Department of Fish and Game. Web site accessed October 11, 2002. http://www.dfg.ca.gov/lands/hatcheryreviewmain.pdf.

California Department of Forestry and Fire Protection. 2002. Jackson demonstration state forest management plan. Web site accessed October 14, 2002. http://www.fire.ca.gov/MiscDocuments/jdsf_mgtplan_master.pdf.

California Geological Survey. 2000. Geologic maps. Web site accessed October 11, 2002. http://www.consrv.ca.gov/cgs/information/geologic_mapping/index.htm.

California Oak Mortality Task Force. 2002. Home page of the California oak mortality task force. Web site accessed October 15, 2002. http://www.suddenoakdeath.org/.

California Polytechnic State University, San Luis Obispo. 2002. Research classification. Web site accessed October 14, 2002. http://agriculture.calpoly.edu/cagr/ari/classification.htm.

California Polytechnic State University, San Luis Obispo, Department of Natural Resources Management (NRM). 2002. Home page of the department of natural resources management. Web site accessed October 14, 2002. http://www.nrm.calpoly.edu/.

California State Board of Forestry and Fire Protection. 1999. Hillslope monitoring program: monitoring results from 1996 through 1998. Web site accessed October 10, 2002. http://www.fire.ca.gov/bof/pdfs/rept9.PDF.

Center for Forestry. 2002a. McIntire-Stennis cooperative forestry program. Web site accessed October 14, 2002. http://www.cnr.berkeley.edu/forestry/research/res_mcst.html.

Center for Forestry. 2002b. Forestry research. Web site accessed October 14, 2002. http://nature.berkeley.edu/forestry/program.html.

Chico College of Agriculture. 2002. ATRC research in progress. California State University, Chico. Web site accessed October 15, 2002. http://www.csuchicoag.org/Agricultural_Teaching_and_Research_Center/Research_in_Progress/ATRC_Research_in_Progress.asp.

Coastal Resources Institute. 2002. Home page of the coastal resources institute. California Polytechnic State University, San Luis Obispo. Web site accessed October 15, 2002. http://www.calpoly.edu/%7Ergp/Research/cri.html.

College of Agricultural Sciences and Technology. 2002. San Joaquin Experimental Range. California State University, Fresno. Web site accessed October 15, 2002. http://cast.csufresno.edu/beef/sjer.htm.

The Collins Companies, Inc. 2002. Collins Almanor forest: an environmental softwood forest. Web site accessed October 15, 2002. http://www.collinswood.com/M2_CertifiedForests/M2H2A2_SCSCertification8.html.

The David and Lucile Packard Foundation. 2000a. Packard foundation dramatically increases its commitment to the environment. Web site accessed October 15, 2002. http://www.packard.org/index.cgi?page=news&year=1998&aid=0008.

The David and Lucile Packard Foundation. 2000b. 2001 grants for conservation: California and the west: conserving California landscapes initiative. Web site accessed October 15, 2002. http://www.packard.org/index.cgi?page=grants&year=2001&id=conscal&parent=conservation.

The David and Lucile Packard Foundation. 2002. The David and Lucile Packard foundation: program overview. Web site accessed October 15, 2002. http://www.packard.org/pdf/2002progover.pdf.

Department of Forestry and Watershed Management. 2002. Resources and facilities available to HSU students. Humboldt State University. Web site accessed October 15, 2002. http://www.humboldt.edu/~for/facilities.shtml.

Fire and Resource Assessment Program (FRAP). 2002a. Information assembled by Dean Cromwell.

Fire and Resource Assessment Program (FRAP). 2002b. Pitch canker task force: senate bill 1712. Web site accessed October 15, 2002. http://www.frap.cdf.ca.gov/pitch_canker/senate_bill_1712.html.

Forest Products Laboratory (FPL). 2002a. About the forest products laboratory. U.S. Forest Service. Web site accessed October 11, 2002. http://www.fpl.fs.fed.us/about.htm.

Forest Products Laboratory (FPL). 2002b. Forest products laboratory research program summary. U.S. Forest Service. Web site accessed October 11, 2002. http://www.fpl.fs.fed.us/program_summary.htm.

Forest Products Laboratory (FPL). 2002c. Research initiative: forest restoration and community economic revitalization through use of small-diameter and underutilized species. U.S. Forest Service. Web site accessed October 11, 2002. http://www.fpl.fs.fed.us/init_sdu.htm.

Forest Science Project. 2002. Home page of the forest science project. Humboldt State University. Web site accessed October 15, 2002. http://www.humboldt.edu/~fsp/.

Graham, Amanda C. and Linda E. Kruger. 2002. Research in adaptive management: working relations and the research process. Pacific Northwest Research Station. Web site accessed October 16, 2002. http://www.fs.fed.us/pnw/pubs/rp538.pdf.

Hopland Research and Extension Center. 2000. Research: current projects. Web site accessed October 14, 2002. http://danrrec.ucdavis.edu/hopland/research_current_projects.html.

Institute for Ecological Tourism. 2002. Home page of the institute for ecological tourism. Humboldt State University. Web site accessed October 15, 2002. http://www.humboldt.edu/~ecotour/.

The James Irvine Foundation. 2002a. Home page of the James Irvine foundation. Web site accessed October 15, 2002. http://www.irvine.org/.

The James Irvine Foundation. 2002b. Sustainable communities. Web site accessed October 15, 2002. http://www.irvine.org/frameset16.htm.

The James Irvine Foundation. 2002c. Sustainable communities: land use initiative. Web site accessed October 15, 2002. http://www.irvine.org/frameset_SCLU.htm.

Legislative Council of California. 1998. Bill number: SB 1712: chaptered 09/22/98. Web site accessed October 15, 2002. http://leginfo.public.ca.gov/cgi-bin/statquery?chapter=713&year=1998.

Mendocino Redwood Company. 2002a. Issues subject index. Web site accessed October 15, 2002. http://www.mrc.com/CurrentRestoration.html.

Mendocino Redwood Company. 2002b. Restoration projects and pictures. Web site accessed October 15, 2002. http://www.mrc.com/Issue.html.

National Center for Ecological Analysis and Synthesis. 2002. Home page of the national center for ecological analysis and synthesis. Web site accessed October 14, 2002. http://www.nceas.ucsb.edu/fmt/doc?/frames.html.

National Marine Fisheries Service. 2001. NMFS strategic plan for fisheries research: appendix A: NMFS scientific enterprise. Web site accessed October 11, 2002. http://www.st.nmfs.gov/st2/s_plan/appendix-a1.pdf.

The Nature Conservancy. 2002. Landscape conservation networks: forest management network. Web site accessed October 15, 2002. http://tnc-ecomanagement.org/Forest/.

New Mexico Water Resources Institute. 2001. California centers for water and wildland resources. Web site accessed October 14, 2002. http://wrri.nmsu.edu/powell/california.html.

Pacific Lumber Company. 2000a. Using the best science available to make decisions—today and tomorrow. Web site accessed October 15, 2002. http://www.palco.com/enviroprograms5.htm.

Pacific Lumber Company. 2000b. Protecting birds, fish and animals as well as the places they live. Web site accessed October 15, 2002. http://www.palco.com/enviroprograms1.htm.

Pacific Lumber Company. 2000c. Background. Web site accessed October 15, 2002. http://www.palco.com/watershedguide.htm.

Pacific Lumber Company. 2001. Our fisheries program. Web site accessed October 15, 2002. http://www.palco.com/fisheries.htm.

Pacific Northwest Research Station. 2002a. Home page of the Pacific northwest research station. U.S. Forest Service. Web site accessed October 11, 2002. http://www.fs.fed.us/pnw/.

Pacific Northwest Research Station. 2002b. The FY 2003 president's proposed budget for PNW. U.S. Forest Service. Web site accessed October 11, 2002. http://www.fs.fed.us/pnw/FY2003Budget/.

Pacific Southwest Research Station. 2002. Home page of the Pacific southwest research station. U.S. Forest Service. Web site accessed October 11, 2002. http://www.psw.fs.fed.us/.

Regional Ecosystem Office. 2002. Regional interagency executive committee. Web site accessed October 16, 2002. http://www.reo.gov/riec/.

Sierra Foothill Research and Extension Center. 2002. Home page of Sierra foothill research and extension center. Web site accessed October 14, 2002. http://danrrec.ucdavis.edu/sierra_foothill/home_page.html.

Sierra Pacific Industries. 2002. Our forests – research and monitoring. Web site accessed October 15, 2002. http://www.sierrapacificind.com/Our_Forests/Research_Monitoring.htm.

Simpson Timber Company. 2001a. Resource management and protection. Web site accessed October 15, 2002. http://www.simpsoncalifornia.com/stewardship/resource_management/resource_management.asp.

Simpson Timber Company. 2001b. Wildlife. Web site accessed October 15, 2002. http://www.simpsoncalifornia.com/stewardship/wildlife_fish/wildlife/wildlife.asp.

Stankey, G.H. and B. Shindler. 1997. Adaptive management areas: achieving the promise, avoiding the peril. Portland, OR: Pacific Northwest Research Station.

Swanton Pacific Ranch. 2002. Home page of the Swanton Pacific ranch. California Polytechnic State University, San Luis Obispo. Web site accessed October 15, 2002. http://www.spranch.org/.

University of California Agricultural Issues Center. 2002. Home page of the university of California agricultural issues center. Web site accessed October 15, 2002. http://www.aic.ucdavis.edu/.

University of California Cooperative Extension. 1999. Home page of the university of California cooperative extension. Web site accessed October 15, 2002. http://danr.ucop.edu/uccelr/uccelr.htm.

University of California Davis School of Veterinary Medicine. 2000. Cattle disease research projects. Web site accessed October 15, 2002. http://www.vetmed.ucdavis.edu/vetext/INF-BE_cca/INF-BE_cca00/INF-BE_cca0003.html.

University of California Division of Agriculture and Natural Resources. 2002. Divisionwide programs. Web site accessed October 14, 2002. http://www.ucdnar.org/internal/programsi.shtml.

University of California Forest Products Laboratory. 2001a. Service to industry program. Web site accessed October 14, 2002. http://www.ucfpl.ucop.edu/SIP.htm.

University of California Forest Products Laboratory. 2001b. UC forest products laboratory annual report July 2000 to June 2001. Web site accessed October 16, 2002. http://www.ucfpl.ucop.edu/AR/AR-01.pdf.

University of California Integrated Hardwood Range Management Program. 2000. Our purpose and mission. Web site accessed October 14, 2002. http://danr.ucop.edu/ihrmp/mission.html.

University of California Integrated Hardwood Range Management Program. 2001. Competitive grants research program. Web site accessed October 15, 2002. http://danr.ucop.edu/ihrmp/research.html.

University of California Natural Reserve System. 1999. Home page of the university of California natural reserve system. Web site accessed October 14, 2002. http://nrs.ucop.edu/.

University of California, Santa Barbara. 2002. California gap analysis home page. Web site accessed October 14, 2002. http://www.biogeog.ucsb.edu/.

Urban Forest Ecosystems Institute. 2002. Home page of the urban forest ecosystems institute. California Polytechnic State University, San Luis Obispo. Web site accessed October 15, 2002. http://www.ufei.calpoly.edu/.

U.S. Cooperative State Research, Education, and Extension Service. 2002. FY 2002 president's budget proposal. Web site accessed October 14, 2002. http://www.reeusda.gov/budget/propose2.htm.

U.S. Environmental Protection Agency. 2002. Research. Web site accessed October 11, 2002. http://www.epa.gov/ebtpages/research.html.

U.S. Forest Service. 2002a. Research and development information at the USDA forest service. Web site accessed October 11, 2002. http://www.fs.fed.us/research/.

U.S. Forest Service. 2002b. Forest service research and development. Web site accessed October 11, 2002. http://www.fs.fed.us/research/briefing papers/California Final 02.07.pdf.

U.S. General Accounting Office. 1999. Federal research: peer review practices at federal science agencies vary. Web site accessed October 11, 2002. http://www.sc.doe.gov/production/bes/rc99099.pdf.

U.S. Geological Survey. 2000. Cooperative research units program. U.S. Department of the Interior. Web site accessed October 11, 2002. http://biology.usgs.gov/coop/index.html.

U.S. Geological Survey. 2002a. The department of the interior fiscal year 2003 interior budget in brief: U.S. geological survey. U.S. Department of the Interior. Web site accessed October 11, 2002. http://www.doi.gov/budget/2003/03Hilites/toc.html.

U.S. Geological Survey. 2002b. About the water, energy, and biochemical budgets program. U.S. Department of the Interior. Web site accessed October 11, 2002. http://water.usgs.gov/webb/about.html.

U.S. Government Printing Office. 2002a. Fiscal year 2002 budget: department of agriculture. Web site accessed October 11, 2002. http://w3.access.gpo.gov/usbudget/fy2002/pdf/agr.pdf.

U.S. Government Printing Office. 2002b. Sudden oak death syndrome control act of 2002. Web site accessed October 15, 2002. http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=107_cong_bills&docid=f:s997es.txt.pdf.

USGS Biological Resources Discipline. 2002. National gap analysis program. Web site accessed October 14, 2002. http://www.gap.uidaho.edu/default.htm.

The William and Flora Hewlett Foundation. 1998. Environment guidelines. Web site accessed October 15, 2002. http://www.hewlett.org/guidelines/environment/environment_top_frm.htm.